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The Effect of Moisture and Fertilizer on Drouth Resistance Factors

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THE EFFECT OF MOISTURE AND FERTILIZER ON DROUTH RESISTANCE FACTORS

By

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THE EFFECT OF MOISTURE AND FERTILIZER

ON DROUTH RESISTANCE FACTORS

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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F. P. B.

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INTRODUCTION

During the weather history of the Upper James Valley of South Dakota, the limiting factor in crop production in 60 percent of the years has been soil moisture (15). Drouths of one kind or another are common experience in the lives of South Dakota farmers.

If we cannot change the climatic factors we must be able to produce crops under existing conditions.

During the early years of agriculture in this state the soil fertility was high and no fertilizer was needed. However, cash cropping has reduced the fertility of the land until fertilizer now must be used to enable the farmer to cover his high fixed costs by high production. His only alternative under limited acreage is to use every technique feasible to avoid bankruptcy. He must produce nearly as much on limited acreage as he did before on unlimited farmland.

The use of fertilizer in the James Valley has been regarded as a gamble because of possible drouth. Thus, the need for information is critical, as farmers are forced to use a relatively new practice with the possibility of unfavorable growing conditions.

It is the purpose of this study to investigate some of the ecological factors which may alleviate drouth injury to crops. The influence of the level of available plant nutrients and certain other soil properties are particular objectives of this study.

REVIEW OF LITERATURE

Terminology

The meaning of drouth resistance has apparently had different meaning among scientists. Levitt (12) reported that drouth resistance as commonly used describes a plant capable of cultivation in dry conditions, no matter what the mechanism of avoiding injurious effects. Maximov (13), pointed out that "the capacity to endure without injury an intense loss of water is one of the most important properties of true drouth resistant plants".

A quantitative means of measuring drouth resistance has been proposed by Stocker (20) as the ratio of the yield under dry conditions compared to yield at optimum moisture. Turmanov (22) stated that plants with drouth resistance can tolerate permanent wilting longer than those not resistant.

Early Research

In the mid nineteenth century, Lawes and Gilbert (11) at the Rothamstad Station in England observed that adequate fertilization had a pronounced beneficial effect on yield of crops even throughout the drouth years. The production of hay was also shown to be influenced by soil fertility even in dry years. Sodium nitrate and manure plots yielded almost ten times more hay than the untreated plots. Soil moisture records indicated that the untreated plot received most of its moisture from the upper eighteen inches of the profile; whereas, the crops on treated plots utilized moisture to nearly four feet.

The effect of soil fertility on the water requirements of crops has been well established by such workers as Briggs and Shantz (3), Kiesselbach (9), and Thom and Holtz (21). Their data indicated a definite reduction of the water requirement by addition of fertilizer when nutrients are a limiting factor.

Recent Research

Harpstead (8) in 1952 studied the influence of nitrogen and phosphorus on wilting of a drouth susceptible barley, using a controlled drouth chamber. Wilting interpreted as injury was delayed the longest by moderate nitrogen applications. In general, additions of phosphorus seemed to increase injury compared to the control. Combinations of nitrogen and phosphorus also resulted in increased injury, with the soil used.

Puhr and others (18) reported the results of spring wheat experiments in Spink County for 1952. Significant response to 40-0-0 and 40-20-0[1] was observed on Houdek loam and Beadle clay loam soils. Phosphorus applied without nitrogen did not increase yield. Wheat responded to fertilizer despite the fact that the area received six inches less than the normal precipitation for the crop season of April through July.

Weldon (26) in Nebraska stated that fertilized winter wheat yielded an average of thirteen bushels per acre more than the unfertilized. He suggests a "rule of thumb" on moisture and fertilization which predicts the amount of fertilizer safe to use from the soil moisture information.

Cheney (4) stated that in the Chestnut zone of Oregon, the need for balancing the rate of application of nitrogen fertilizer with the supply of available moisture is well recognized. Typical applications are 20-30 pounds of nitrogen per acre for wheat following fallow. However, when

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[1]Pounds per acre of nitrogen, phosphorus and potash respectively

moisture supplies are inadequate no nitrogen may be needed.

Nicholson (17) in Iowa reported a fifty bushel increase in corn yield due to adequate fertility during a very dry season. Reasons for this increase are explained as follows:

1. Nitrogen plots silked two weeks ahead of the control
2. The soil was very nitrogen deficient
3. Corn roots were found to penetrate only 2 to 2½ feet deep in the control, but 4 to 4½ feet deep in the plots which received nitrogen

Hanks and Tanner (7) reported that yields of oats and corn were higher per inch of soil moisture used under high nitrogen as compared to low nitrogen. Thomas (23) working with irrigated grasses on Pierre clay found that high rates of residual nitrogen and nitrogen and phosphorus yielded 201 and 306 pounds of hay per acre respectively, for each inch of moisture used. Untreated plots yielded only 113 pounds of hay per inch of moisture used.

Russell and Danielson (19) concluded that moisture stored in the soil profile is very important in the growth of corn. On a well drained soil, corn can utilize moisture at depths of five feet or more.

Nelson (16), however, stated that the use of fertilizers to increase efficiency of crops is sometimes disappointing. When fertilizers were used where there was no deficiency and where there was extremely limited moisture, yields were no different, regardless of fertility level. Nelson also stated that nitrogen deficiency symptoms appear during drouth periods. This results because the upper layers contain most of the available nitrogen, and as these layers dry out, an important supply of nitrogen is lost to the plant.

Misra (14), investigating drouth resistance in corn, found that strains having superior root systems not only were able to survive drouth, but also made better recovery.

Fehrenbacker and Snider (6) in an attempt to discover the reason for differences in yield of corn on Cisne silt loam (a Planosol), noted marked differences in root extension. They found that plant roots were penetrating through the claypan on the fertilized plot and were able to exploit more soil volume for moisture.

Kmoch and others (10) at Nebraska in root studies with winter wheat, have shown that a deeper, more vigorous root system is formed under adequate nitrogen fertilization except at very low moisture levels. Great differences in the depth of root penetration were observed between the fertilized and non-fertilized plots when 3.3 or 5.6 inches of supplemental water was added. However, when the soil profile was moistened to field capacity to six feet, the roots of the unfertilized wheat extended slightly deeper.

These data seem to contradict results reported by Bosmark (1) from which he concluded that nitrogen suppresses root extension by its effect in increasing production of the auxin 1-naphlylacetic acid, which suppresses root elongation.

Weaver (25) has stated that adsorbtion of water and nitrates at various depths is directly correlated with abundance of roots in the given layer.

EXPERIMENTAL PROCEDURE

Greenhouse Experiments 1955

The objectives of the 1955 greenhouse experiments were to establish the influence of fertilizer on barley varieties with differential drouth resistance.

A sand-soil mixture was used of 1:1 ratio in order to lower native fertility of the growing medium. The fertilizer was added as powdered ammonium nitrate and treble superphosphate, and was mixed thoroughly with the soil and then potted.

The varieties of barley were selected for their drouth resistance. Previous research by Chisholm (5) indicated that varieties could be classified as susceptible, intermediate and resistant. The varieties used in the present study were Moore, Trebi and Plains.

Barley seeds were planted 12 per pot and later thinned to seven. The soil was weighed and watered to field capacity (moisture equivalent percentage). The soil in the pots was then allowed to dry out until the plants first showed signs of wilting, then they were again watered to field capacity.

The harvesting was done by clipping the plants with scissors and drying and weighing the dry matter.

Field Experiments 1955

Field experiments in 1955 were designed to determine the effect of fertilizer on the yield of barley varieties of varied drouth resistance. The effect of fertilizer on yield of oats was also sought.

In 1955 field experiments were carried on at four locations; Redfield, Highmore, central Hand County and southern Faulk County. Experiments at Redfield were located on Beotia silt loam. Three varieties of barley were used; Plains, Velvon 11 and Montcalm, Velvon 11 and Montcalm being close analogs of Trebi and Moore. One experiment was planted on April 15 and another on an adjacent site on April 29.

Two experiments were placed on Williams loam at Highmore. The fertilizer was plowed under at one site and disced under on the other.

Experiments with oats on Houdek loam were approximately 20 miles apart. One experiment was localed in Faulk County and one in Hand County.

At all locations which had only one variable such as fertilizer, a common randomized block design was utilized. However, when the variable of varieties was included, a split plot design was used. Main plots were varieties and the fertility levels were randomized within each main plot. Three replications were used at all sites in 1955.

In 1955 the fertilizer was broadcast and disced under on all but one experiment. At Highmore in one experiment, the fertilizer was first broadcast and then plowed under.

The type of fertilizer used in all cases was ammonium nitrate for nitrogen and treble superphosphate for phosphorus.

The fertilizer applications used in 1955 are presented in Table 1. The fertilizer application is given as the amount in pounds per acre of nitrogen, phosphorus pentoxide and potash respectively.

Table 1. Fertilizer Applications Used in Field Experiments[1]

1955		1956		
Four Experiments	Two Experiments	Two Experiments	One Experiment	One Experiment
0- 0- 0	0- 0- 0	0- 0- 0	0- 0- 0	0- 0- 0
20- 0- 0	16- 0- 0	40- 0- 0	40- 0- 0	0-60- 0
20-20- 0	33- 0- 0	80- 0- 0	80- 0- 0	40-60- 0
80- 0- 0	66- 0- 0	160- 0- 0	160- 0- 0	80-60- 0
80-40- 0	0-22- 0	0-40- 0	320- 0- 0	120-60- 0
	16-22- 0	80-40- 0		120- 0- 0
	33-22- 0			
	66-45- 0			

[1]Pounds per acre of N, P_2O_5 and K_2O, respectively

The small grains were all planted at the rate of five pecks per acre. Experiments were harvested by taking four square yards of grain per plot. The samples were then dried, threshed and yields computed.

Greenhouse Experiments 1956

Greenhouse experiments in 1956 were designed to determine the effect of fertilizer on hardened and non-hardened plants of Plains barley. Hardening was accomplished by differential moisture treatments.

In 1956 the unaltered greenhouse soil (Vienna loam) was used and the powdered ammonium nitrate and treble superphosphate were applied in two placement techniques. The "deep" application was placed all at one level about four inches from the top of the soil. The "mix" application was mixed thoroughly with all the soil in the pot.

In order to determine the effect of fertilizer on hardened and non-hardened plants, two moisture levels were established. The "high" moisture level was not allowed to dry below 50 percent available soil moisture and the "low" treatment was not watered until the available moisture was below 20 percent. The wilting point was estimated from the moisture equivalent percentage by the use of the equation by Briggs and Shantz (2):

$$\text{Wilting percentage} = \frac{\text{moisture equivalent percentage}}{1.84}$$

The split plot experimental design was used, with the main plots being moisture, the first split fertility, and the second split placement of fertilizer.

Wilting notes were taken at two stages of growth, jointing and heading. Plants to be wilted were placed on a large turntable and subjected to high temperature and low humidity in the greenhouse under normal light conditions. At each stage the plants to be submitted to stress were brought to field moisture capacity and placed on the turntable. Visual notes on wilting were taken at intervals to pinpoint permanent wilting. The wilting notes taken correspond to the standards indicated in Figure 3. When plants were permanently wilted, they were removed and recovery allowed by adding moisture to above field capacity and allowing them to stand in a cool shaded area. After recovery notes were taken the plants were harvested for dry matter.

Field Experiments 1956

The objectives of the 1956 field experiments were to establish the effect of fertilizer and moisture on yield, moisture use efficiency and root distribution.

Barley experiments in 1956 were established at Tulare and corn experiments were carried out at Yankton, Tulare and Redfield, Early season hail destroyed the corn at Redfield and sorghum was planted in the same location.

Two moisture levels were established on the barley on La Delle silt loam at Tulare and the sorghum experiment on Beotia silt loam at Redfield.

M-1 No irrigation
M-2 One five inch irrigation early in the season

Six moisture levels were used in the corn experiment on Sarpy loamy sand at Yankton.

M-1 No irrigation
M-2 One irrigation in tassel to silk-brown stage to bring root zone to field capacity
M-3 Irrigated only in tassel to early dent stage, keeping soil moisture above 30-40 percent of available moisture
M-4 Irrigated in all stages except from tassel to silk-brown
M-5 Irrigated through tassel-silk stage, none thereafter
M-6 Irrigated to maintain root zone above 30-40 percent available moisture through all stages

An ordinary randomized block corn experiment was set up on Hand loam near Tulare. Nitrogen fertilizer was side-dressed after the second cultivation. The experiments on Beotia, La Delle and Sarpy soils were of the split plot design with moisture levels as the main plots and fertility as the sub-plots. Four replications were used on field experiments in 1956 with the exception of the sorghum experiment at Redfield, where six replications were employed. Fertilizer was broadcast and disced under in the sorghum experiment at Redfield and the barley experiment at Tulare. However, half of the nitrogen and all of the phosphorus was broadcast and plowed down in the Yankton corn experiment. The remainder of the nitrogen was side dressed at the last cultivation.

The fertilizer applications used in 1956 are listed in Table 1.

Small grain planting and harvesting methods were the same as those used in 1955. The corn experiment at Yankton on Sarpy loamy sand was heavily planted and thinned to 17,500 plants per acre. The nitrogen side-dressing experiment on corn at Tulare had an approximate population of 10,000 plants per acre.

Corn yields were measured by picking all the ears in 52 feet of row. Moisture samples were taken by cutting sections of 12 to 15 ears of corn from each plot and determining their moisture content. The yields presented are calculated at 15 percent moisture. In harvesting the sorghum 1/500 acre samples were cut, bundled and weighed in the field. Plant samples were taken at each soil moisture level to determine moisture percentage. Yields were computed on a 15 percent moisture basis in the forage.

Soil Moisture Sampling

Throughout the 1956 season moisture samples were taken with an Oakfield probe and dried at 105°C to determine soil moisture. One foot increment samples were taken to four feet in three replications of each experiment. Fertilizer treatments sampled in 1956 are presented in Table 2.

Table 2. Soil Plot Treatments Sampled for Soil Moisture in 1956

Tulare Barley	Redfield Sorghum	Yankton Corn
0- 0- 0	0- 0- 0	0- 0- 0
80- 0- 0	0-40- 0	0-60- 0
80-40- 0	80- 0- 0	120- 0- 0
	80-40- 0	120-60- 0

Two moisture levels were sampled in each experiment.

Moisture percentages were calculated on oven dry basis, and inches of available water were arrived at using the following equation:

Inches of water = (field moisture % - 15 atmosphere %) X bulk density X thickness of sample in inches

Root Separation

Root separation was initiated on the Hand silt loam at Tulare when inspection of the roots of corn indicated that more roots were penetrating the plow sole on the nitrogen fertilized plot than on the unfertilized. Roots appeared to grow down to the hard layer and then grow parallel with it, with very few roots going through. However, on the fertilized plot the roots appeared to form an almost normal pattern.

Root samples were taken by the monolith method, i.e. uniform blocks of soil were taken from the profile and removed to the laboratory for separation. At Tulare the 36" x 48" x 6" profile was divided into twenty-four 6" x 12" x 6" samples which were carefully removed and packaged. These samples were dried slowly in a crop drier for six days. Profiles at Yankton were divided into twelve 12" x 12" x 6" samples and handled in the same manner as the Tulare samples. Adjacent plots were sampled to reduce the incidence of soil variation.

The Tulare samples were wet sieved in a forty mesh sieve made from ordinary carburetor screen. This part of the procedure removed the fine sand, silt and clay particles. The mixture of sand and roots was then transferred to a glass cylinder and the roots were separated by decantation. Large Buechner funnels were utilized to catch the roots. The soil-free root samples were then dried, weighed and ashed to correct error introduced by mineral particles adhering to the roots.

Losses due to handling by this procedure appeared negligible, as close inspection of water in which the wet sieving was done failed to disclose any roots. It is possible that the surface tension of the water over the fine screen prevented root loss. Where extraneous matter such as weed seeds occurred in the sample they were removed by hand.

The soils in the Yankton corn experiment presented a new problem. Due to the coarseness of the soil, practically none of the soil was removed by wet sieving with fine screen. Use of a gravity table proved successful in concentrating the roots to about 1/25 the original soil volume. The principle is simple; the sand particles being more dense, tend to climb up the slope of the gravity table while the roots remain behind.

The screen of the gravity table, originally designed for corn and legume and grass seed separation, was fitted with a medium weight muslin cover. The fan and motor were boxed tightly with weatherstripping and calking compound to prevent sand leaking onto the motor.

Each sample was spread thinly on the muslin apron and allowed to shake until all the coarse sand had been separated. The time required for separation could be controlled by adjusting the slope of the table.

Checks with several samples indicated that over 95 percent of the roots were saved by using the gravity table.

Samples of roots when concentrated from the gravity table were separated by decantation from a glass cylinder as described in the Tulare experiment.

The corrected root weights are reported in grams of roots at each depth for each profile.

Although the gravity table proved to be a satisfactory means of separating the sand from the roots, several precautions should be mentioned.

1. It is essential that a constant vacuum is maintained above the machine to prevent dusty conditions.
2. Bearings of the gravity table should be of the sealed, dustless type.
3. The power source used should be internally cooled or sealed off from the blower.

Soils of Experimental Fields

The description of soils on experimental sites as described by Westin and others (27) is as follows:

<u>Beotia silt loam</u>

A well drained friable soil occurring on level positions near streams in the Lake Dakota Plain, of post-Mankato glacial age. The soil profile is permeable, yet has good water holding capacity.

<u>Profile Description</u>

A_1	0-13"	Black friable silt loam of granular structure
B_2	13-23"	Very dark greyish brown grading to olive brown, friable silt loam of prismatic structure
C_{ca}	23-40"	Yellowish brown, friable silt loam highly calcareous, sometimes slightly saline
C	40-60"	Light yellowish brown, friable silt loam, calcareous, sometimes slightly saline

<u>Hand loam</u>

A well drained zonal Chernozem-Chestnut intergrade developed in slightly stratified, medium textured, glacio-fluvial deposits of Mankato age. Hand soils have dark grey, slightly hard granular A_1 horizons, dark grey, slightly hard prismatic B horizons and moderately developed C_{ca} horizons in pale yellow calcareous fine sand.

Profile Description (Hand loam)

A_1	0-6"	Very dark grey, friable loam of granular structure
B_2	6-20"	Very dark greyish brown, friable loam of prismatic structure
C_{ca}	20-35"	Light olive brown, friable loam, strongly calcareous
C	35-60"	Light olive brown, friable stratified, fine sandy loam, calcareous

Houdek loam

This soil occurs on well drained sites of the northern James Valley. The parent material is calcareous, glacial till of the Mankato age.

La Delle silt loam

La Delle soils are moderately well drained and occur on level stream terraces on high bottoms along glacial streams. The parent material is friable silty clay loam or silt loam stream deposited sediment. This soil is moderately permeable but has good water holding capacity. Gravel is sometimes encountered at depths greater than 36 inches. These soils are very similar to the Beotia silt loam described before with the exception that they are stream laid rather than lacustrine sediments.

Profile Description

A_1	0-9"	Black friable silt loam of granular structure
B_2	9-18"	Black to very dark brown silty clay loam of coarse prismatic structure
C_{ca}	18-28"	Dark greyish brown silt loam or silty clay loam, strongly calcareous alluvium, slightly saline
C	28-60"	Dark greyish-brown, silt loam or silty clay loam, calcareous alluvium, slightly saline

Sarpy loamy sand

A light colored alluvial soil developed in sandy and gravelly flood plain sediments. The soil in the experiment was a Sarpy loamy sand with heavier textured substratum occurring at random thickness and depth.

Profile Description[1] (Sarpy loamy sand)

1.	0-5"	Greyish brown to dark brown, slightly coherent loamy fine sand, slightly acid reaction
2.	5-14"	Light greyish brown to brown, loamy fine sand or fine sand, neutral in reaction
3.	14-30"	Pale brown to brown loamy fine sand or fine sand, neutral or slightly calcareous
4.	30-48"	Similar colors and texture to the above horizon, but is mottled with dark brown and usually is slightly to moderately calcareous

Williams loam

A well drained Chestnut soil developed in medium to fine textured Late Wisconsin glacial till.

Laboratory Analyses

The 15 atmosphere percentage of soil moisture was determined on Hand loam, La Delle silt loam and Sarpy loamy sand by using the pressure membrane apparatus. The Hand and Sarpy soils were analyzed by depth for nitrate using the phenoldisulfonic acid method.

Weather Data

Rainfall data were obtained at the experimental site wherever possible, but records of the nearest U. S. Weather Bureau station were used for temperature and relative humidity.

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[1]Established series description as revised by J. Thorpe, Division of Soil Survey, BPISAE, USDA

RESULTS AND DISCUSSION

An attempt was made to determine the influence of nitrogen and phosphorus on small grain and corn grown under drouth conditions. Resistance to wilting, recovery from wilting, moisture use efficiency, root distribution and ultimate yield were some of the criteria used to determine drouth reaction. Where applicable, statistical significance was determined by analysis of variance. Least significant differences are given for each experiment.

Greenhouse Experiments 1955

The initial objective in this study was to determine whether some varieties were more responsive than others to fertilizer under dry conditions. The plants were subject only to soil drouth and not atmospheric drouth.

Table 3. Influence of Fertilizer on Dry Matter Yield of Three Barley Varieties, Greenhouse 1955

Treatment	Grams of Dry Matter			
Lbs./Acre	Plains	Trebi	Moore	Average
0- 0- 0	1.85	1.88	2.38	2.04
40- 0- 0	3.02	3.38	4.59	3.66
40-40- 0	3.61	3.66	4.55	3.94
120- 0- 0	4.79	5.73	6.02	5.51
200- 0- 0	3.16	4.12	4.67	3.98
Average	3.28	3.75	4.44	

	Varieties	Treatment
LSD[1](.05)	0.34	0.36

[1]Least significant difference at the 5% confidence level

Results of this experiment indicate that varieties are not severely affected by soil drouth alone. Two hundred pounds of nitrogen alone depressed the dry matter yield. This may be due to inadequacy of phosphorus at the 200 pound nitrogen level. Comparison of these three varieties by dry matter weight may not be proper as the Plains variety is a short straw variety whereas Moore is a long straw barley. Trebi is intermediate in straw length.

The secondary objective of greenhouse study was to determine at what stage of plant growth fertilizer begins to influence the dry matter production under conditions of soil drouth. Moore barley was grown in 2 quart culture vessels with nine soil treatments, each replicated nine times. At each stage of development sampled, three replications were harvested for dry matter yield.

Table 4. Influence of Fertilizer on Dry Matter Yield at Three Stages of Growth. Moore Barley, Greenhouse 1955

Treatment	Grams of Dry Matter Produced Per Pot		
	Stage		
Lbs./Acre	Jointing	Heading	Maturity
0- 0- 0	1.97	4.20	3.65
40- 0- 0	2.70	4.92	6.75
0-40- 0	2.45	3.03	5.03
40-40- 0	3.38	4.95	6.32
80- 0- 0	3.29	4.99	7.93
80-80- 0	3.76	6.94	7.08
120- 0- 0	4.13	5.96	7.22
160- 0- 0	4.26	8.84	8.49
200- 0- 0	2.81	8.23	5.19
LSD (.05)	1.26	1.50	1.68

Analysis of variance in yield data shows that the effects of the lower levels of nitrogen alone and phosphorus alone were significant only in the mature stage. However, the 40-40-0 treatment was significant in the jointing and mature stages and the 80-80-0 treatment was significant in the heading stage. A slight depression can also be noted in this experiment at the highest level of nitrogen. This experiment indicates that barley dry matter yields are influenced by fertilizer even in early stages, although more mature plants respond to lower rates of fertilizer.

Field Experiments 1955

Barley Experiments

Three varieties of barley were planted on the early date experiment at about the optimum time, April 15. The late date experiment was planted on April 29. Pre-season soil moisture was in short supply and dry conditions prevailed with no substantial rains until May 23. The late planted experiment was very slow to emerge as it was planted when the surface soil was very dry.

Differences due to fertility were easily discernible at mid-season on the early date experiment, but as the crop neared maturity, the differences became less apparent. Differences due to fertility were never obvious in the late planted experiment.

Statistical analysis of the yield data shows no significance for fertility in either experiment. However, high significance between varieties was realized.

Yields and rainfall data for Redfield barley experiments are presented in Tables 5 and 6.

Table 5. Effect of Fertilizer on Grain Yield of Three Varieties of Barley, Beotia Silt Loam, Spink County 1955

1. Early Date of Planting

	Yield in Bushels per Acre			
Treatment	Plains	Velvon 11	Moore	Average
0- 0- 0	47.18	43.40	31.37	40.65
20- 0- 0	40.88	45.43	39.33	41.88
20-20- 0	41.74	49.10	36.52	42.45
80- 0- 0	41.29	43.03	38.15	40.82
80-40- 0	47.77	49.29	37.82	44.96
Average	43.97	46.05	36.64	

	Varieties	Treatments
LSD (.05)	5.29	N.S.[1]

2. Late Date of Planting

Treatment	Plains	Velvon 11	Moore	Average
0- 0- 0	40.14	39.74	23.94	34.61
20- 0- 0	36.96	29.56	34.75	33.76
20-20- 0	41.70	36.08	24.31	34.03
80- 0- 0	30.97	39.40	20.94	30.44
80-40- 0	50.88	34.85	27.52	37.75
Average	40.13	35.93	26.09	

	Varieties	Treatments
LSD (.05)	4.45	N.S.

[1]Not significant at the 5% confidence level

Table 6. Monthly Rainfall for 1955 Season at Redfield, South Dakota

Rainfall (inches)			
October	.02	April	.96
November	.18	May	2.71
December	.98	June	3.93
January	.16	July	2.35
February	1.05	August	2.12
March	.03	September	.82
	Total 15.31		

Two barley experiments on Williams loam at Highmore were seeded and fertilized on consecutive dates. In one experiment the fertilizer was spread and then plowed under. The other experimental area was plowed, fertilizer spread and then lightly disced. Plains, Velvon 11 and Montcalm were the barley varieties used.

A severe spring drouth occurred at Highmore in 1955. No significant moisture was received from April 24 until May 23. Relief from drouth brought quick recovery on the plowed under experiment but early differences due to fertility were quickly masked as the season progressed. The "plowed under" experiment showed significance for varieties only, while the "disced in" showed no significance for either varieties or fertilizer.

The lack of grain yield response due to fertility after observation of response in color and vegetative growth can be partially accounted for by two reasons. 1. Great variability of the soils within the experiment. 2. The grain yield potential was determined before the relief from drouth.

Yield and rainfall data for Highmore barley experiments are presented in Tables 7 and 8.

Table 7. Influence of Fertilizer on Yield of Three Varieties of Barley - Williams Loam, Hyde County 1955

I. Fertilizer Plowed Under

Treatment	Plains	Yield in Bushels per Acre Velvon 11	Montcalm	Average
0- 0- 0	45.77	53.06	45.92	48.25
20- 0- 0	54.61	65.27	35.52	51.80
20-20- 0	53.76	68.37	45.88	56.00
80- 0- 0	57.05	49.91	48.39	51.78
80-40- 0	60.94	50.91	46.84	52.90
Average	54.43	57.50	44.51	

	Varieties	Treatments
LSD (.05)	5.42	N.S.

II. Fertilizer Disced In

Treatment	Plains	Velvon 11	Montcalm	Average
0- 0- 0	33.59	43.59	31.71	36.30
20- 0- 0	33.71	42.85	30.12	35.56
20-20- 0	29.19	38.18	29.34	32.24
80- 0- 0	29.71	34.08	27.64	30.48
80-40- 0	29.74	41.62	24.90	32.09
160- 0- 0	34.37	40.96	29.08	34.80
Average	31.71	40.21	28.80	

	Varieties	Treatments
LSD (.05)	N.S.	N.S.

Table 8. Monthly Rainfall for 1955 Season at Highmore, South Dakota

Rainfall (inches)			
October	1.65	April	.57
November	.50	May	2.78
December	.10	June	4.41
January	.07	July	3.91
February	.70	August	.41
March	.07	September	1.25
	Total 16.42		

Field experiments have shown that the drouth tolerance as indicated by Chisholm (5) is correct. However, experiments did not show that any variety responded significantly to fertilizer. Plains did show a trend toward response in two experiments.

Figure 1 illustrates the differences in growth early in the season that were not apparent in the yield.

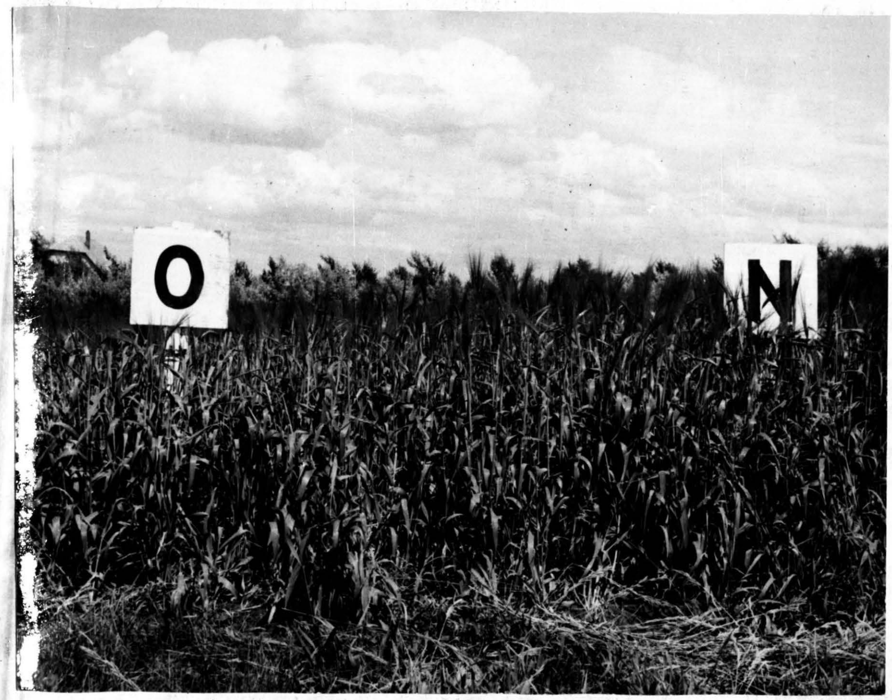


Figure 1. Influence of nitrogen on growth of barley - Williams Loam, Hyde County 1955

Oats Experiments

Significant yield increases from fertilizer applications were not obtained in oats experiments on Houdek loam at two locations in 1955. Growth following the spring drouth was indicative of response to fertilizer but the difference was not manifest in the yield. The low yield of the Hand County experiment was partially due to severe incidence of leaf rust. Yield data are presented in Table 9.

Table 9. Influence of Fertilizer on Grain Yield of Oats - Houdek Loam, Hand and Faulk Counties 1955

Treatment Lbs./Acre	Hand County	Faulk County
0- 0- 0	17.91	34.09
16- 0- 0	19.91	33.94
33- 0- 0	16.58	33.32
66- 0- 0	18.47	40.23
0-22- 0	16.30	30.51
16-22- 0	18.69	32.02
33-22- 0	15.24	36.61
66-45- 0	22.50	32.78
LSD (.05)	N.S.	N.S.

Greenhouse Experiments 1956

Plant injury due to soil drouth and high temperature was assessed by determining hours of exposure necessary to produce permanent wilting. Soil in the pots was brought to field capacity and plants were exposed to high temperature and low humidity. A large turntable was employed to keep the plants moving during the stress period. A hygrothermograph was used to check the conditions of the drouth. The average daylight temperature was 90°F and the average night temperature was 75°F. Relative humidity ranged from 20 to 30 percent.

Figure 2 shows the turntable and the hygrothermograph in use. Figure 3 is the injury key used for wilting determinations. A reading of three was considered the permanent wilting point.

Figure 2. Turntable with barley being subjected to drouth. A hygrothermograph has been placed at the center of the turntable. Greenhouse 1956.

Figure 3. Injury key used in wilting notes. Greenhouse 1956. Injury of three was considered permanent wilting.

Table 10 shows considerable, though variable, influence of fertilizer on plant response at the low moisture levels. At high moisture levels there appeared to be very little influence of fertilizer.

Table 10. Effect of Moisture, Fertilizer and Fertilizer Placement on Wilting of Plains Barley, Greenhouse 1956 *

Treatment	Fertilizer Placement	Hours of exposure before permanent wilt: Low Moisture	High Moisture
0- 0- 0		49	21
40- 0- 0	Deep	80	21
40- 0- 0	Mix	55	23
80- 0- 0	Deep	45	30
80- 0- 0	Mix	60	24
160- 0- 0	Deep	54	35
160- 0- 0	Mix	49	21
0-40- 0	Deep	54	20
0-40- 0	Mix	47	26
80-40- 0	Deep	48	23
80-40- 0	Mix	68	21

*Average of three replications

Recovery notes were taken on permanently wilted plants five days after restoring them to favorable conditions. Rating scale of recovery was as follows:

Rating	Explanation
1	Death of plant
2	Plant regained turgor but no regrowth
3	Regrowth within five days

Recovery differences were very great. The control plants did not recover at either high or low moisture levels. Partial recovery only was obtained at the 80-0-0, 160-0-0 and 80-40-0 treatments at the high moisture levels. In the low moisture levels nearly all fertilized plants recovered except in the case of phosphorus alone. Specific drouth reaction of the recovered plants is shown in Table 11.

Table 11. Recovery From Drouth of Joint Stage Plains Barley as Influenced by Moisture, Fertilizer and Fertilizer Placement, Greenhouse 1956

Treatment	Fertilizer Placement	Recovery Rating of Barley Plants Low Moisture	High Moisture	Average
0- 0- 0		1.0	1.0	1.0
40- 0- 0	Deep	2.67	1.0	1.75
40- 0- 0	Mix	2.33	1.0	
80- 0- 0	Deep	2.33	1.33	1.75
80- 0- 0	Mix	2.0	1.33	
160- 0- 0	Deep	2.67	1.67	2.08
160- 0- 0	Mix	2.67	1.33	
80-40- 0	Deep	2.67	1.67	2.08
80-40- 0	Mix	3.0	1.0	
0-40- 0	Deep	1.33	1.0	1.50
0-40- 0	Mix	2.67	1.0	
Average		2.20	1.19	

Legend: 1. Death
2. Regained turgor but no regrowth
3. Regrowth within five days

LSD (.05)	Moisture	Treatment	Placement
	0.42	0.28	N.S.

Dry matter yields were taken at two stages of the experiment. In the jointing stage significance was obtained for moisture and fertility but not for placement. However, the heading stage also showed significant differences due to placement, with the mix application producing the highest yield.

Significance for placement on the more mature barley indicates that the root system was able to exploit more volume for nutrients and moisture than the less mature plants.

Efficiency of moisture use as indicated by evapotranspiration per gram of dry matter produced was most evident in the 80-40-0 treatment in both the jointing and heading stages. However, all the fertilizers increased moisture efficiency with the exception of 160 pounds of nitrogen alone and 40 pounds of phosphorus alone in the jointing stage. Yield and evapotranspiration data are shown on Tables 12 and 13.

Table 12. Influence of Moisture, Fertilizer and Fertilizer Placement on Yield and Evapotranspiration of Plains Barley, Jointing Stage, Greenhouse 1956

Treatment Lbs./Acre	Fertilizer Placement	Low Moisture: Yield in grams of dry matter	Low Moisture: Evapotranspiration per gram	Low Moisture: Evapotranspiration percent of check	High Moisture: Yield in grams of dry matter	High Moisture: Evapotranspiration per gram	High Moisture: Evapotranspiration percent of check	Mean Yield
0- 0- 0		.71	676	100.0	1.18	631	100.0	.94
40- 0- 0	Deep	.64	627	92.7	1.22	567	89.9	.98
40- 0- 0	Mix	.80	582	86.1	1.24	581	92.1	
80- 0- 0	Deep	.85	565	83.6	1.16	574	91.0	.98
80- 0- 0	Mix	.74	630	93.2	1.19	558	88.4	
160- 0- 0	Deep	.70	663	98.1	0.97	635	100.6	.86
160- 0- 0	Mix	.66	721	106.7	1.11	592	93.8	
80-40- 0	Deep	.80	584	86.4	1.30	540	85.6	1.04
80-40- 0	Mix	.79	562	83.1	1.26	554	87.8	
0-40- 0	Deep	.78	627	92.8	1.37	532	84.3	1.02
0-40- 0	Mix	.78	619	91.6	1.14	636	100.8	
Mean Yield		.75			1.19			

LSD (.05) Moisture .10

Treatment .09

Placement N.S.

Table 13. Influence of Moisture, Fertilizer and Fertilizer Placement on Yield and Evapotranspiration of Plains Barley, Heading Stage, Greenhouse 1956

		Low Moisture			High Moisture			
Treatment Lbs./Acre	Fertilizer Placement	Yield in grams of dry matter	Evapotranspiration per gram	Evapotranspiration per-cent of check	Yield in grams of dry matter	Evapotranspiration per gram	Evapotranspiration per-cent of check	Mean Yield
0- 0- 0		2.14	631	100.0	2.94	728	100.0	2.54
40- 0- 0	Deep	2.20	595	94.3	3.30	622	85.4	2.83
40- 0- 0	Mix	2.15	594	94.1	3.66	589	80.9	
80- 0- 0	Deep	2.40	574	91.0	3.35	636	87.4	2.94
80- 0- 0	Mix	2.26	491	77.8	3.74	514	70.6	
160- 0- 0	Deep	2.16	559	88.6	3.56	562	77.2	2.92
160- 0- 0	Mix	2.30	543	86.1	3.68	504	69.2	
80-40- 0	Deep	2.16	608	96.4	3.95	489	67.2	3.09
80-40- 0	Mix	2.23	575	91.1	4.01	483	66.3	
0-40- 0	Deep	2.20	610	96.7	3.06	701	96.3	2.67
0-40- 0	Mix	2.13	581	92.1	3.30	599	82.3	
Mean Yield		2.21			3.46			

LSD (.05)	Moisture	.08	Placement Means	Deep	Mix
	Treatment	.05	Low Moisture	2.21	2.20
	Placement	.02	High Moisture	3.36	3.56

Field Experiments 1956

Barley Experiments

An experiment was conducted under irrigation to determine the effect of fertilizer on small grain at two levels of soil moisture. The M-1 level was not irrigated and the M-2 level was irrigated with a five inch application early in the season to fill the four foot profile to field capacity.

Temperatures remained normal until June 9-14 when the daily highs ranged from 94-102°F for six days. The low relative humidity for this period ranged from 16-39%. Damage was severe in surrounding small grain fields. Varieties in the immediate area having less drouth resistance than Plains were damaged beyond recovery.

Figure 4 graphically summarizes the factors involved in the injury of small grain. Data for the graph are taken from observations at the Redfield Development Farm.

Yield and rainfall data are presented in Tables 14 and 15.

Table 14. Influence of Moisture and Fertilizer on Grain Yield of Plains Barley - La Delle Silt Loam, Spink County 1956

Treatment	M-1	M-2	Average
	Bu./A		
0- 0- 0	16.22	26.89	21.55
40- 0- 0	18.06	25.43	21.74
80- 0- 0	18.05	23.89	20.98
160- 0- 0	18.34	21.26	19.80
0-40- 0	18.97	24.58	21.78
80-40- 0	19.54	25.84	22.69
Average	18.27	24.65	
LSD (.05)	Moisture 5.04 bushel	Fertility N.S.	

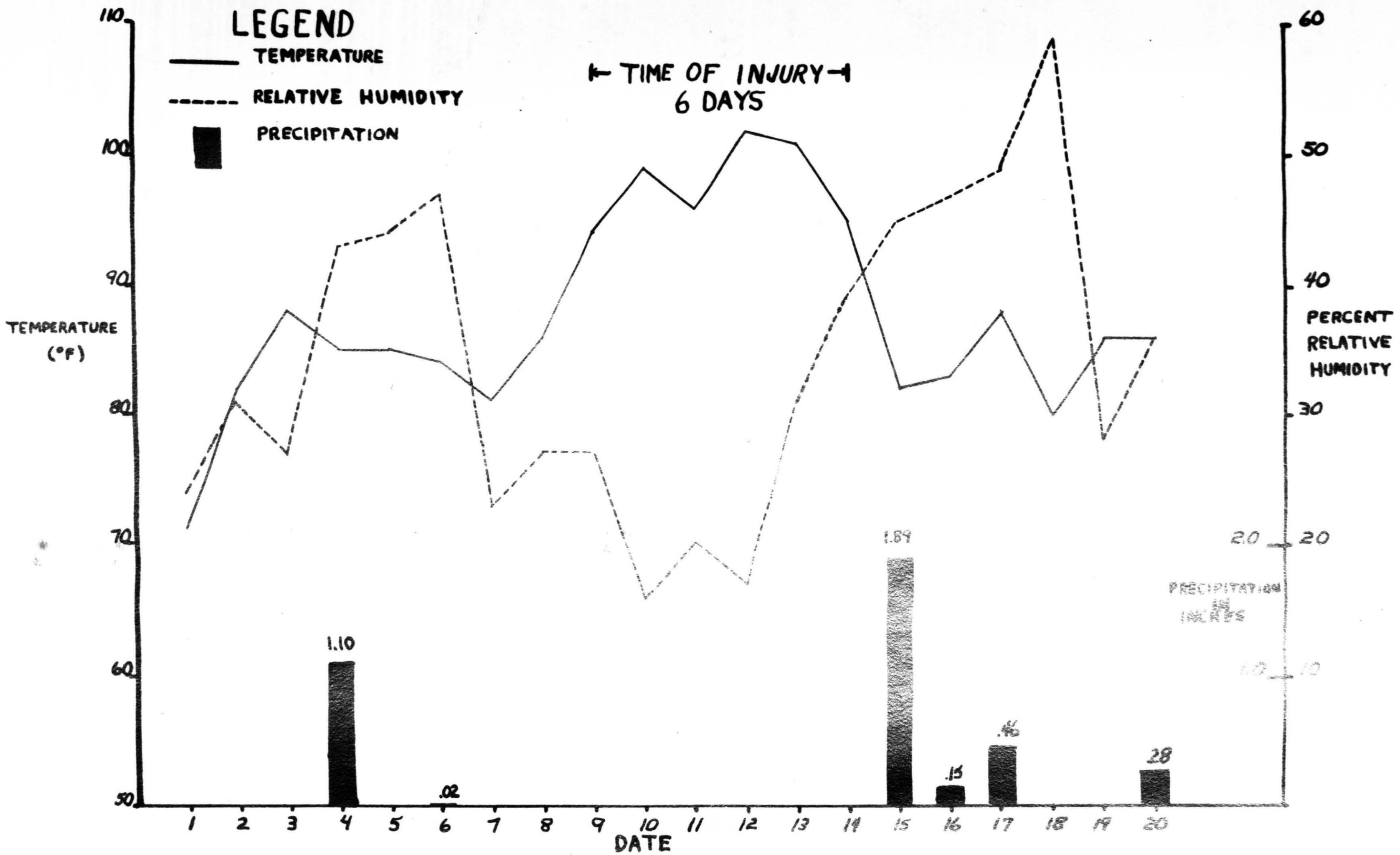


Figure 4. MAXIMUM TEMPERATURE, MINIMUM RELATIVE HUMIDITY AND RAINFALL DATA FOR JUNE 1-20 1956 REDFIELD IRRIGATION FARM

Table 15. Monthly Rainfall for 1956 Season at Tulare, South Dakota

	Inches		
October	trace	April	.98
November	.34	May	1.78
December	.94	June	4.55
January	.47	July	3.83
February	.23	August	3.30
March	.61	September	.30
	Total 17.33		

Table 16 indicates that fertility has a definite effect on efficiency of moisture use. In both the high and low levels of soil moisture, the 80-0-0 treatment resulted in the most efficient moisture use. Close agreement is found between field and greenhouse data. Increases in both fertility and moisture added to the efficiency of moisture use.

Seasonal use of preplant soil moisture and moisture use efficiency are presented in Table 16.

Table 16. Influence of Moisture and Fertilizer on Moisture Use Efficiency of Plains Barley - La Delle Silt Loam, Spink County 1956

Treatment	Inches of Available Soil Moisture on Indicated Dates May 17	June 1	June 20	July 14	Soil Moisture Used	Yield Bu/A	Bushels/Inch of Preplant Soil Moisture Used
M-1							
0- 0- 0	8.09	5.69	4.85	2.16	5.63	15.57	2.77
80- 0- 0	7.12	5.88	5.24	2.44	4.68	20.67	4.42
80-40- 0	9.22	6.50	6.03	2.82	6.40	19.10	3.32
M-2							
0- 0- 0	10.29	7.42	5.90	3.01	7.28	28.07	3.86
80- 0- 0	9.85	7.43	6.37	3.64	6.22	24.89	4.00
80-40- 0	10.54	6.70	6.10	2.91	7.62	25.44	3.62

Corn Experiments

Experiments were designed at Redfield and Yankton with moisture levels as the main plots and fertility treatments as the sub-plots. Two moisture levels were used at Redfield and six at Yankton.

The purpose of the experiments was to determine the effect of fertilizer and moisture on yield, moisture use efficiency, and root distribution.

A corn experiment was established at Tulare on Hand loam to determine the effect of side-dressed nitrogen on yield, moisture extraction and root distribution.

Redfield Experiment

Corn was the initial crop planted at Redfield. A violent hail storm destroyed the corn on June 24.

Sorghum was planted on June 29 on the same experimental layout. The M-2 moisture level was established soon after sorghum emergence by adding five inches of irrigation water. A cool July and August delayed the maturity and the experiment was harvested for forage after the first frost. Yield data are presented in Table 17.

Table 17. Influence of Moisture and Fertilizer on Forage Yield of Sorghum - Beotia Silt Loam, Spink County 1956

Treatment	M-1	M-2	Average
	Tons per Acre		
0- 0- 0	4.71	6.23	5.47
40- 0- 0	4.52	6.04	5.28
80- 0- 0	4.66	6.47	5.56
160- 0- 0	4.67	6.20	5.44
0-40- 0	4.78	6.04	5.41
80-40- 0	4.67	5.81	5.24
Average	4.67	6.13	
LSD (.05)	Moisture 0.97 tons	Fertility N.S.	

No significant yield differences due to fertility were obtained. However, the addition of five inches of moisture very significantly affected the yield.

Moisture sampling studies revealed that during the season there was no stress on the sorghum at either moisture level. It appears that though no stress periods were encountered in which the wilting point was approached, the "available" moisture is not equally available throughout the 0-15 atmosphere tension range. This is in agreement with the results of

Wadleigh and Ayres (24). Thus the irrigated plots produced a greater yield. The available moisture at each moisture level is shown in Table 18.

Table 18. Available Soil Moisture Under Sorghum at Harvest - Beotia Silt Loam, Spink County 1956

Depth	Available inches of soil moisture M-1	M-2
0-12	.63	.95
12-24	1.22	1.40
24-36	2.26	1.94
36-48	3.25	2.92
Total	7.36	7.23

The available moisture percentages for the two profiles are nearly identical. However, it is evident that the sorghum on M-1 plots obtained most of its moisture from the upper two feet, whereas that on M-2 plots obviously used moisture from the entire profile. It appears that moisture use efficiency in this experiment was increased with increasing total available moisture.

Tulare Experiment

Haapala hybrid corn 36 inches high was side-dressed with ammonium nitrate on July 19 with five treatments; 0, 40, 80, 160, and 320 pounds of nitrogen per acre. The soil moisture conditions at side-dressing time were very unfavorable. Total rainfall from side-dressing time to harvest was 4.80 inches. Frost was exceedingly late, contributing to the dryness and quality of the corn. Root excavations were made at harvest time and root density in each horizon was determined.

Table 19 shows yield as influenced by nitrogen application.

Table 19. Effect of Side-Dressed Nitrogen on Grain Yield of Corn - Hand Loam, Spink County 1956

Treatment	Yield in Bu./Acre
0- 0- 0	32.1
40- 0- 0	45.6
80- 0- 0	44.3
160- 0- 0	42.2
320- 0- 0	42.9
LSD (.05) 7.22 bu./acre	

The response to nitrogen reached a maximum at the first increment. Stand or moisture or both possibly limited yield at application levels above 40 pounds of nitrogen per acre. The influence of nitrogen on top growth of corn is shown in Figure 5.

0-0-0 80-0-0

Figure 5. Influence of side-dressed nitrogen on corn. Hand Loam, Spink County 1956

The response of corn to side-dressed nitrogen under situations of limited moisture indicates that when there is a deficiency of nitrogen, addition of nitrogen fertilizer will not be injurious to the plant. Even large amounts such as 320 pounds of nitrogen per acre maintained a significant yield increase over the unfertilized and depressed the yield less than three bushels from the 40 pound level.

The Hand loam soil on the experimental site had formed a dense plow sole at six inches below the soil surface. Examination of the roots revealed that the roots of fertilized plants were extending through the plow sole while those of the unfertilized plants were mostly growing laterally along the surface of the plow sole. Figures 6 and 7 show the excavation pit and the dense plow sole.

Root distribution, nitrate content and available moisture content at harvest time as presented in Table 20 indicate that roots of unfertilized plants were unable to exploit thoroughly a given volume of soil for nutrients and water. The effect of nitrogen on root distribution is shown in Figure 8. There are indications that the nitrate from the side-dressed fertilizer did leach downward as the concentration of nitrate was nearly constant to a level of 24 inches, where 3.6 parts per million were present.

Table 20. Influence of Side-Dressed Nitrogen on Corn Root Distribution, Nitrate Content and Available Moisture in the Soil Profile at Harvest. Hand Loam, Spink County 1956

Depth	No Nitrogen		40 lbs. of Nitrogen	
	PPM NO_3	Grams of Roots per $\frac{1}{4}$ ft^3	PPM NO_3	Grams of Roots per $\frac{1}{4}$ ft^3
0- 6	1.6	20.93	2.9	22.25
6-12	3.4	4.33	2.7	16.47
12-18	1.6	2.72	2.8	3.51
18-24	1.3	1.91	3.6	2.43
24-30	0.6	1.49	0.5	2.02
30-36	1.5	0.61	0.9	1.64
36-42	2.0	0.59	1.0	0.73
42-48	0.8	0.38	1.1	0.47
Average	1.60		1.94	
Inches of soil moisture remaining in profile at tension below 15 atmospheres	0.57		-0.18	

Figure 6. Pit for corn root sampling. Hand Loam, Spink County 1956

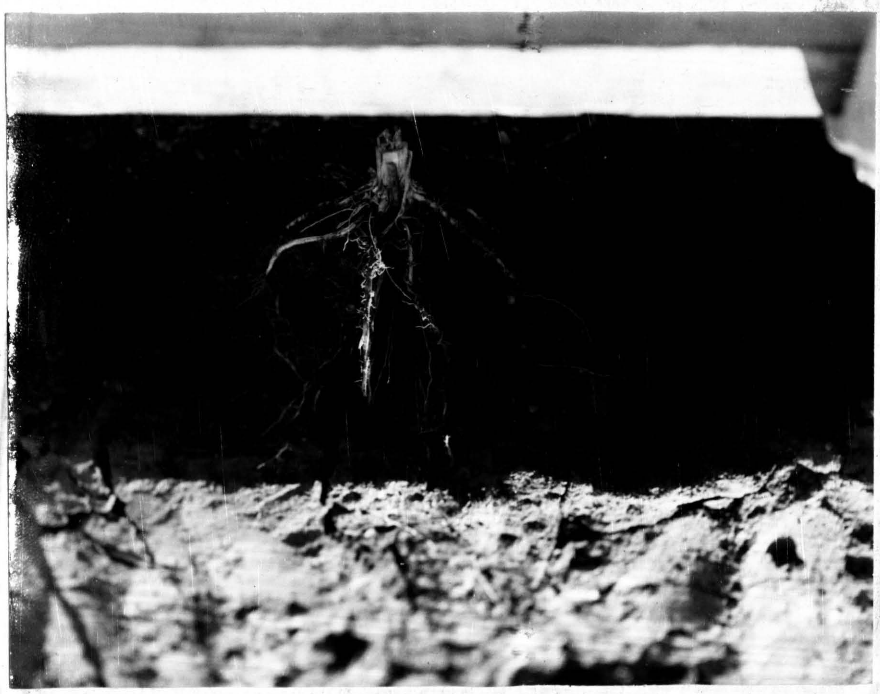


Figure 7. Corn roots on fertilized site. Top horizon has been removed to expose the dense plow sole. Hand Loam, Spink County 1956

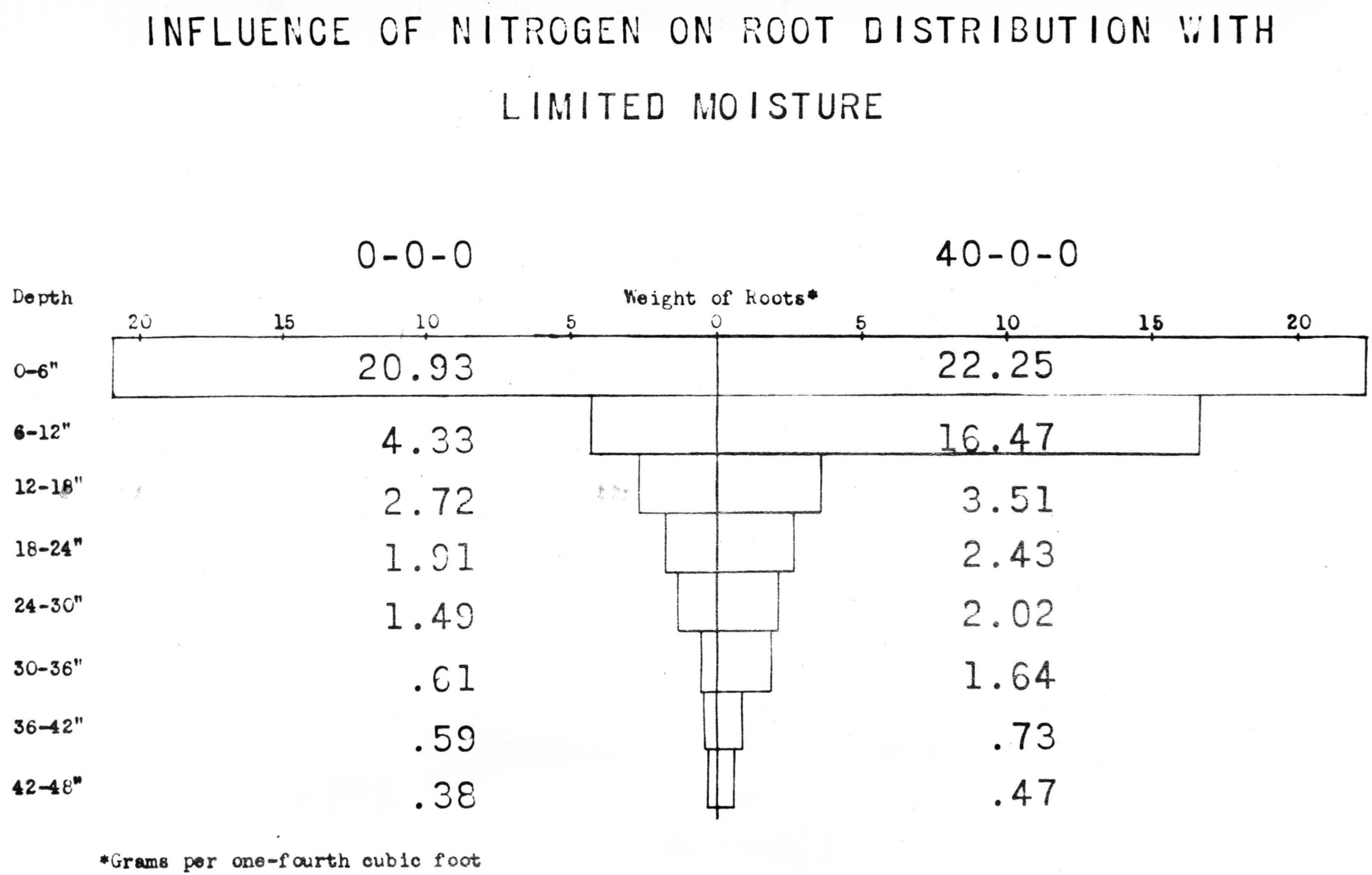


Figure 8. Influence of fertilizer on corn root distribution with limited moisture - Hand Loam, Spink County 1956

A difference in depth of moisture use was also apparent. Soil moisture was used to below the 15 atmosphere percentage in the top three feet of the profile on the fertilized plot and only the top two feet on the unfertilized. Of the three replications sampled, there was a net difference of 0.75 inches of moisture that the corn fertilized with 40 pounds of nitrogen per acre was able to utilize.

Yankton Experiment

Inasmuch as the yearly rainfall was more than nine inches below normal for the Yankton area, the weather conditions were ideal for drouth study. The site selected was on a sandy, well drained soil, similar to the Sarpy loamy sand mapped in Nebraska. The experiment was designed to test the performance of the hybrid corn at six fertility treatments, each under six different moisture regimes, the fertility plots being sub-plots of moisture treatments.

The experiment was planted on May 11 to Curry's Hybrid #60 and the stand later thinned to 17,500 plants per acre. Warm dry weather promoted rapid early growth.

Interference with moisture levels by seasonal rainfall was very slight as most of the showers during the growing season were below .25 inch. However, subsurface lateral seepage was considerable when soil differences were encountered. Layers of silt and clay occurring at random depths and thickness caused movement laterally from irrigated to non-irrigated areas, resulting in yields abnormally high for the amount of rainfall received. Dryland corn in adjacent fields was very nearly a failure due to the drouth.

Even with the interference with the moisture levels by lateral seepage, all of the irrigated plots produced yield increases above the M-1 or non-irrigated plot.

Combined nitrogen and phosphorus at the 80-60-0 and 120-60-0 fertility levels were the only treatments that caused significantly higher yields than the unfertilized. High amounts of nitrogen without phosphorus did not increase the yield significantly. Yield depression in the 0-60-0 treatment lacked only 0.6 bushel of being significant at the five percent level, as an average of all moisture levels.

Yield and statistical information is presented in Table 20. Rainfall data are presented in Table 21.

Moisture sampling was done throughout the season on four fertility treatments on each of the M-1 and M-5 moisture levels. Three replications were sampled in this manner at bi-monthly intervals. Soil moisture data were very erratic due to soil variability. A study of moisture and yield data disclosed the almost complete dependence of yield on available moisture. In nearly all plots there was a direct relationship between soil moisture and yield, regardless of fertility treatment. Fairly intensive soil moisture sampling showed that the soil variability interfered so seriously with moisture treatment that no conclusions could be drawn concerning moisture use as a function of fertility.

The extremes in soil variability found in the experimental site are shown in Figure 9.

Table 21. Effect of Moisture and Fertility on Grain Yield of Corn - Sarpy Loamy Sand, Yankton County 1956

Moisture Treatment	Yield Bu./Acre 0-0-0	0-60-0	40-60-0	80-60-0	120-60-0	120-0-0	Average
M-1	81.2	43.6	72.8	89.5	94.0	66.9	74.7
M-2	88.6	66.3	96.3	102.5	108.0	96.0	93.1
M-3	89.9	59.4	108.3	121.2	117.9	87.8	97.4
M-4	88.0	72.2	126.8	119.3	137.2	120.8	110.7
M-5	70.7	86.8	96.3	117.4	115.5	103.2	98.3
M-6	104.2	91.4	106.4	97.5	119.5	76.6	99.2
Average	84.3	66.8	101.3	107.9	115.4	91.8	
LSD (.05)	Moisture 18.0		Fertility 18.1				

Analysis of Variance

Source	Degrees of Freedom	Mean Square	
Replications	3	5,488.09	**
Moisture	5	3,340.49	*
Error A	15	858.77	
Fertility	5	6,312.81	**
Fertility x Moisture	25	532.61	N.S.
Error B	90	996.34	

**Significant at the 1 percent confidence level
* Significant at the 5 percent confidence level
N.S. Not significant

Table 22. Monthly Rainfall for 1956 Season at Yankton, South Dakota

	Inches		
October	.86	April	2.62
November	.02	May	1.43
December	1.02	June	.48
January	.19	July	2.89
February	.23	August	2.98
March	.32	September	.62
	Total 13.66		

Root samples were taken at a site where little interference with moisture levels had occurred. As a consequence, the yields of the non-irrigated plots where the sampling was done are much lower than the average. Root density, parts per million of nitrate and yield of each plot are shown in the following table.

Table 23. Influence of Moisture and Fertilizer on the Root Density, Nitrate Content and Corn Yield - Sarpy Loamy Sand, Yankton County 1956

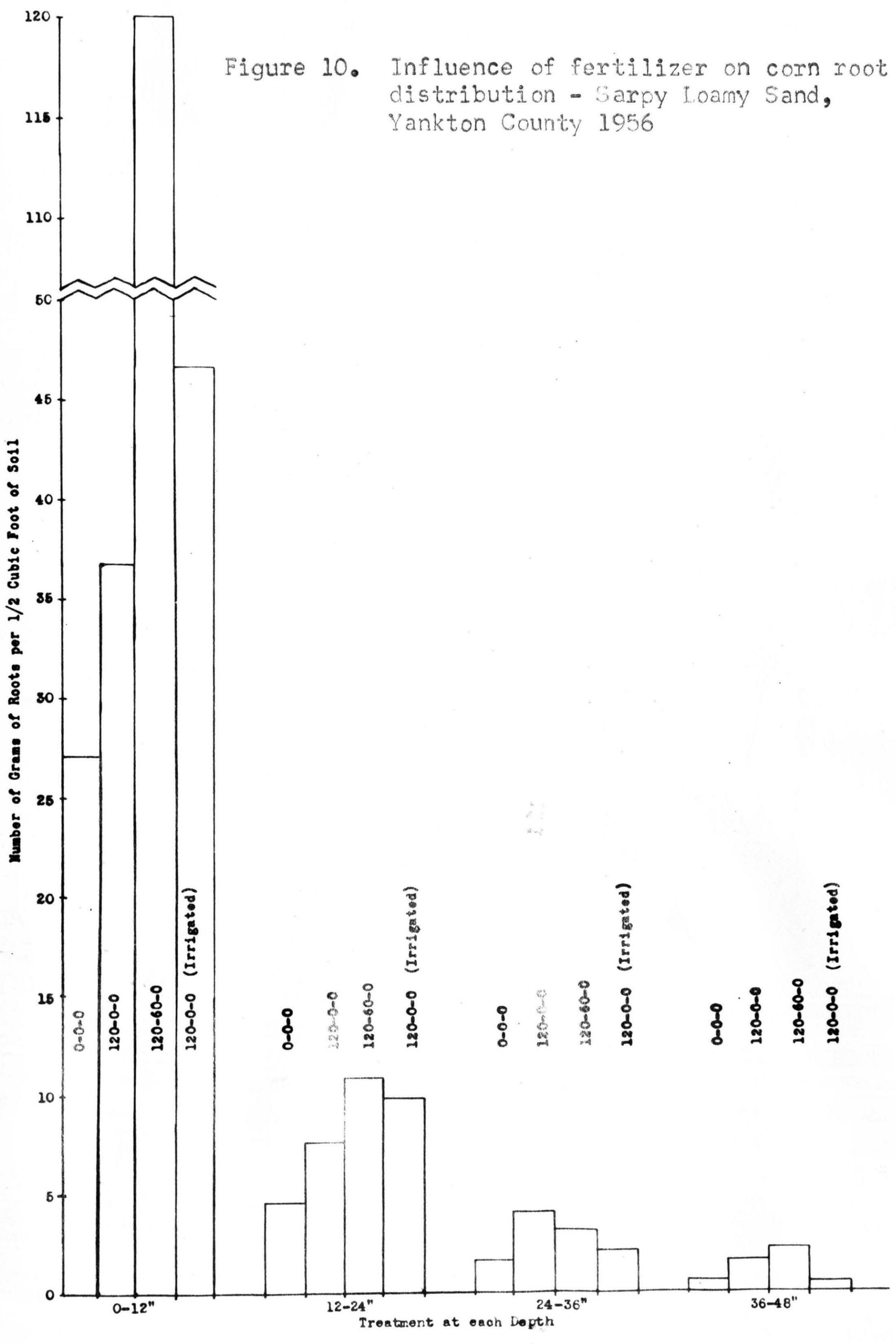
	Grams of Roots per one-half cubic foot of soil at the indicated depths								
	0-12 in.		12-24 in.		24-36 in.		36-48 in.		
Treatment	Grams of Roots	PPM NO_3	Grams of Roots	PPM NO_3	Grams of Roots	PPM NO_3	Grams of Roots	PPM NO_3	Corn Yield Bu./A
0- 0- 0 M-1	27.16	.52	4.50	.45	1.51	.35	0.41	.25	18.9
120- 0- 0 M-1	36.79	.70	7.54	.45	4.01	.35	1.50	.35	45.3
120-60- 0 M-1	117.10	220.00	10.87	55.00	3.24	59.00	2.07	52.00	85.0
120- 0- 0 M-5	46.51	.63	9.74	.45	2.14	.33	0.43	.23	55.9

Figure 9. Extremes of soil variance of Sarpy loamy sand. Yankton County 1956. The profile on the left has a silt layer only about one inch thick while in the profile on the right the silt layer is nearly 18 inches in thickness.

The influence of nitrogen and phosphorus on root distribution is very apparent from data presented in Table 23. Root weights are consistently greater on fertilized plots than on the control. At the 36-48 inch depth, the weight of roots was three to four times as large in the fertilized plots as in the control at the M-1 moisture level. However, root weights were smaller in the 24-48 inch depth of the 120-0-0 irrigated plot than in the dryland. Irrigation seemed to concentrate the roots in the top two feet of soil.

Nitrate content of soils fertilized with nitrogen was only very slightly higher than that of the control. However, the site with 120 pounds of nitrogen and 60 pounds of phosphorus per acre contained over 100 times the amount of nitrate at each depth than the other sites. It is possible that either the nitrate did not leach or the phosphorus created a "snowball" effect on the nitrate producing organisms of the soil.

A graphic view of the influence of fertilizer on root weight and distribution is presented in Figure 10.



INFLUENCE OF NITROGEN ON ROOT DISTRIBUTION

SUMMARY

Experiments were conducted in the field and greenhouse to determine what effect, if any, soil factors subject to management practices may have on drouth resistance of certain crops. Although results are not conclusive, certain quite definite effects were noted which appear to the author to be worth reporting.

Greenhouse experiments with barley indicated that dry matter production could be significantly increased with addition of fertilizer under conditions of an ordinary soil drouth. So called drouth-susceptible varieties actually produced more dry matter per unit of fertilizer than the drouth-resistant varieties. A probable explanation may be that the resistant varieties are short-strawed while the susceptible varieties are long-strawed. High levels of nitrogen and nitrogen and phosphorus gave significant responses in dry matter production at the jointing stage of development, but low levels of fertilizer did not give responses until the heading or mature stage.

Damage and recovery from desiccation and soil drouth were markedly affected by differential moisture and fertility treatment. Largest differences were apparent between low and high moisture levels. It is probable that the low moisture plants were partially hardened against drouth and desiccation whereas those plants under high moisture conditions were never stressed for water. Permanent wilting was delayed approximately twice as long in the hardened plants as in the non-hardened plants.

Recovery from wilting was also more pronounced on the hardened

plants, although the unfertilized plants under both moisture levels did not recover. However, during the growth of the plant the moisture use efficiency was greatest on plants growing without moisture stress.

The effect of fertilizer on wilting damage and recovery was not as pronounced as the effect of moisture levels. Even though the results on wilting were quite erratic, nearly all of the treatments resulted in delay of wilting, with the exception of high nitrogen, and phosphorus alone. Low levels of nitrogen increased recovery on the low moisture levels but partial recovery on high moisture was gained only by 80 and 160 pounds of nitrogen.

Response to fertilizer treatment by barley in field experiments was not attained in either 1955 or 1956. Some experiments showed a trend toward response but as the yield variation was high it can possibly be attributed to experimental error. However, it must be recognized that the soils at the sites of the experiments were not severely lacking in plant nutrients. Differences in drouth resistance between varieties were observed. Moore and Montcalm, the susceptible varieties, were always lower yielding than Plains, the resistant variety.

No significant differences in yield due to fertility were found with Plains barley on La Delle silt loam. However, it is of interest to note that even after exposure to extreme desiccation for six days, (Figure 4) there was still recovery and no reduction of yield due to added fertilizer. Yield per inch of preplant soil moisture used ranged from 2.77 bushels on the control to 4.42 bushels on 80 pounds of nitrogen per acre.

Significant yield increases resulted from supplemental moisture in sorghum and corn in 1956, but no effect of fertilizer was noted on sorghum. Corn experiments on Sarpy loamy sand and Hand loam both responded well to added fertilizer. A trend toward reduction in yield by phosphorus added without nitrogen was apparent on the Sarpy loamy sand. Preseason soil tests showed that phosphorus was not in limited supply. Even though phosphorus was apparently not limiting, the 120 pound nitrogen alone treatment did not produce a significant yield increase over the control, as an average for all moisture levels.

No reduction of yield was experienced on Hand soil with up to 320 pounds of side-dressed nitrogen per acre. At this high level the yield increase was still significant over the check.

The effect of soil properties on root distribution of corn is very apparent from root studies on a loam soil with a semi-dense plow pan (Hand) and a permeable loamy sand (Sarpy). On the Hand loam roots having penetrated the dense plow sole weighed nearly four times as much in the plot fertilized with 40 pounds of nitrogen per acre as in the unfertilized. Root weights were also higher through the entire profile. Complete exploitation of the root zone for moisture is demonstrated by the fact that .75 inch more soil moisture was utilized in the fertilized plots than in the unfertilized. Soil moisture was extracted below the 15 atmosphere percentage in the top three feet of the profile.

Root weights in the permeable Sarpy loam were greater at all depths in the fertilized profile than the unfertilized site at M-1 moisture level. However, the plots having received 120 pounds of nitrogen at the M-5 moisture level were characterized by the heavy concentration of roots in the top two feet of the soil profile.

CONCLUSIONS

1. It is probable that drouth resistance is increased by supplemental fertilization on soils similar to those used in this investigation if an original fertility deficiency exists.
2. It appears that fertilizer has less effect on drouth resistance of non-hardened than of hardened plants under conditions of extreme desiccation.
3. Nitrogen, and perhaps nitrogen and phosphorus together, increase moisture use efficiency, where the native soil fertility level is marginal or low.
4. It is very doubtful that nitrogen and proper combinations of nitrogen and phosphorus cause depression of crop yield under conditions of moisture stress.
5. Phosphorus applied alone on coarse textured soils have resulted in yield depressing trends where no phosphorus deficiency occurs.
6. Applications of fertilizer nitrogen and nitrogen plus phosphorus increased corn root weights at all depths in the soil profiles examined.
7. The amount of available soil moisture at planting time appeared to be an important factor in determining final yield in some of the experiments conducted.

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